

SPECIFICATION
DIHALIDE, POLYMER COMPOUND AND METHOD FOR
PRODUCING THE SAME

5 TECHNICAL FIELD

[0001] This invention relates to a dihalide, a polymer compound and a method for producing the same, and more particularly to a dihalide having a specific structure in its main chain and a polymer compound, and a method for producing the polymer compound
10 obtained by using the dihalide as a starting material.

BACKGROUND ART

[0002] Recently, an aromatic polymer compound is noticed as a material having heat resistance, electrochemical activity and fluorescence, and the application and development, for example, as a
15 fluorescence material are advanced. For example, polyaniline, polythiophene and the like are expected to have a function as an active material for a cell through the application of its electrochemical redox reaction (A. G. MacDiarmid et al., PCT Int. Appl. 82-US299) (Yamamoto, Matsunaga, "Polymer Battery",
20 Kyoritsu Publication (1990)).

Also, it is expected that a polyparaphenylene-based polymer has a high heat resistance, and poly(9,10-dihydrophenanthrene-2,7-diyl) is synthesized, in which benzene rings in a polyparaphenylene are bonded with an ethylene group (polym. Bull., vol. 30, p285 (1993)).

25 Non-patent document 1 : A. G. MacDiarmid et al. PCT Int. Appl. 82-US299, Yamamoto, Matsunaga, "Polymer Battery", Kyoritsu Publication (1990)

Non-patent document 2 : polym. Bull., vol. 30, p285 (1993)

DISCLOSURE OF THE INVENTION

30 PROBLEMS TO BE SOLVED BY THE INVENTION

[0003] However, the conventionally developed poly(9,10-dihydrophenanthrene-2,7-diyl) is insoluble in a solvent, so that it has restrictions such as limitation of moldability and so on. Therefore,

it is demanded to develop polyparaphenylene-based polymers having an electrochemical activity, a heat resistance, a fluorescence and a high solubility.

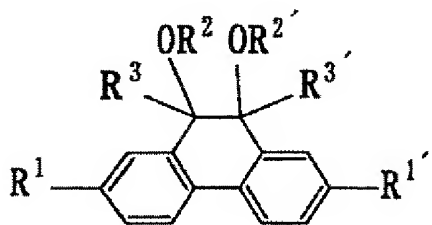
[0004] It is, therefore, an object of the invention to provide a novel poly(9,10-dihydrophenanthrene-2,7-diyl) introduced with a suitable substituent for solubilization and capable of expecting the application as a functional material, and a method for producing the same.

MEANS FOR SOLVING PROBLEMS

[0005] The inventors have made various studies about a dihalide and dehalogenation of the dihalide in order to achieve the above objects and found a polymer compound according to the invention and a method for producing the same.

[0006] That is, the dihalide according to the invention is represented by the following formula:

[Formula 1]



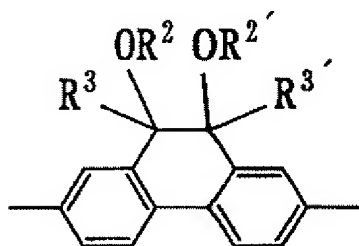
(wherein R^1 and $R^{1'}$ represent a halogen, R^2 and $R^{2'}$ represent an alkyl group or a silyl group having a substituent, and R^3 and $R^{3'}$ represent hydrogen or an alkyl group, provided that R^1 and $R^{1'}$, R^2 and $R^{2'}$, and R^3 and $R^{3'}$ may be different or the same).

[0007] In a preferable embodiment of the dihalide according to the invention, the silyl group having the substituent is at least one selected from the group consisting of $Si(CH_3)_3$, $Si(n-C_4H_9)_3$, $Si(t-C_4H_9)_3$, $Si(CH_3)_2(C_6H_5)$ and $Si(CH_3)_2(n-C_{18}H_{37})$.

Moreover, in another preferable embodiment of the dihalide according to the invention, the alkyl group is an alkyl group having a carbon number of 1-20.

[0008] Also, the polymer compound according to the invention is characterized by having a structure represented by the following formula in its main chain:

[Formula 2]

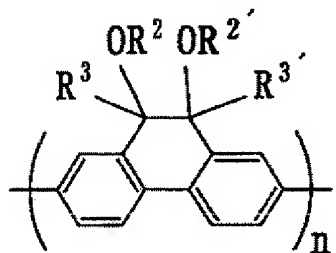


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(wherein R^2 and $R^{2'}$ represent an alkyl group or a silyl group having a substituent, and R^3 and $R^{3'}$ represent hydrogen or an alkyl group).

[0009] The polymer compound according to the invention is preferable to be represented by the following formula:

10 [Formula 3]



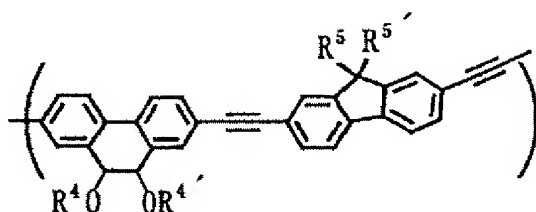
(wherein R^2 and $R^{2'}$ represent an alkyl group or a silyl group having a substituent, R^3 and $R^{3'}$ represent hydrogen or an alkyl group, and n represents a polymerization degree and is 5-1000.)

15 [0010] Also, the polymer compound according to the invention is preferable to be composed of a copolymer comprising a structure represented by the formula described in claim 4 and another structure.

[0011] In a preferable embodiment of the polymer compound according to the invention, the copolymer is at least one selected from the group consisting of the following formulae:

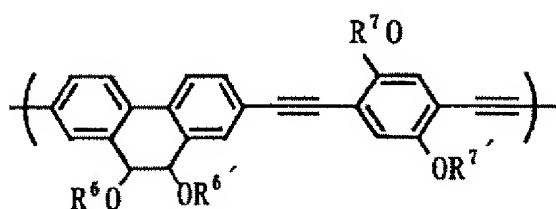
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[0012] [Formula 4]



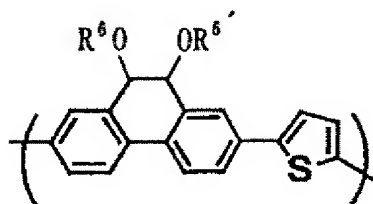
(wherein R⁴, R^{4'}, R⁵ and R^{5'} represent an alkyl group, provided that R⁴ and R^{4'}, and R⁵ and R^{5'} may be different or the same),

5 [0013] [Formula 5]



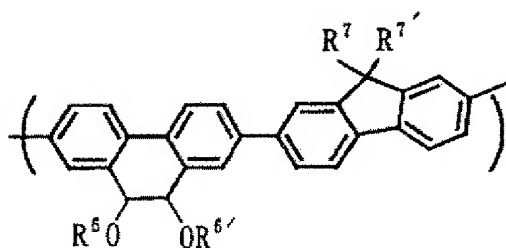
(wherein R⁶ and R^{6'} represent a silyl group having a substituent, and R⁷ and R^{7'} represent an alkyl group, provided that R⁶ and R^{6'}, and R⁷ and R^{7'} may be different or the same),

10 [0014] [Formula 6]



(wherein R⁶ and R^{6'} represent a silyl group having a substituent, provided that R⁶ and R^{6'} may be different or the same),

[0015] [Formula 7]

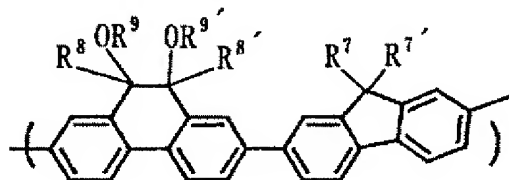


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(wherein R⁶ and R^{6'} represent a silyl group having a substituent, and

R^7 and $R^{7'}$ represent an alkyl group, provided that R^6 and $R^{6'}$, and R^7 and $R^{7'}$ may be different or the same), and

[0016] [Formula 8]



5 (wherein R^7 , $R^{7'}$, R^8 , $R^{8'}$, R^9 and $R^{9'}$ represent an alkyl group, provided that R^7 and $R^{7'}$, R^8 and $R^{8'}$, and R^9 and $R^{9'}$ may be different or the same).

[0017] The method for producing the polymer compound according to the invention is characterized by dehalogenation-
10 polymerizing the dihalide to obtain the polymer compound according to the invention.

[0018] In a preferable embodiment of the method for producing the polymer compound according to the invention, the dehalogenation-polymerization is carried out in the presence of a
15 palladium or nickel compound.

EFFECTS OF THE INVENTION

[0019] The dihalide according to the invention develops an advantageous effect capable of providing a useful conjugated polymer compound as an electrochemically and engineeringly functional
20 material.

[0020] The polymer compound and the method for producing the same according to the invention develop an advantageous effect capable of simply providing a novel polyparaphenylene-based polymer having moldability owing its solubility, a heat resistance, a
25 fluorescence and an electrochemical activity. Particularly, a thin film can be obtained by selecting an alkyl group or a silyl group having a substituent and using a method comprising steps of dissolving in a solvent and then casting.

BRIEF DESCRIPTION OF THE DRAWINGS

30 [0021] FIG. 1 is a NMR spectrum of a compound 6 in Formula 25.

FIG. 2 is a NMR spectrum of a compound 7 in Formula 17.

FIG. 3 is a NMR spectrum of a compound 8 in Formula 17.

FIG. 4 is a NMR spectrum of a compound 9 in Formula 17.

FIG. 5 is a NMR spectrum of a compound 10 in Formula 17.

5 FIG. 6 is a NMR spectrum of a compound 11 in Formula 17.

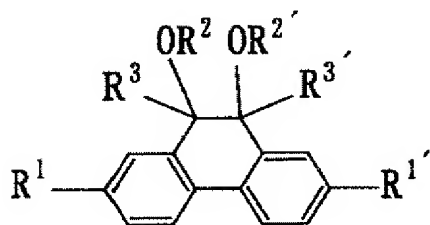
FIG. 7 is a NMR spectrum of a compound 15 in Formula 19.

FIG. 8 is a NMR spectrum of a compound 16 in Formula 19.

BEST MODE FOR CARRYING OUT THE INVENTION

[0022] That is, the dihalide according to the invention is
10 represented by the following formula.

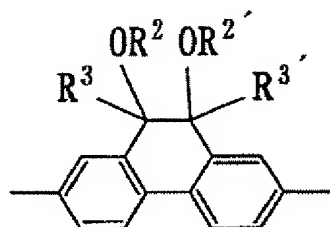
[Formula 9]



[0023] In the above formula, R¹ and R^{1'} represent a halogen
selected from Cl, Br, I and so on, and are preferably Br in view of
15 synthesis easiness and high reactivity. The halogens selected as R¹
and R^{1'} may be different from each other, but are preferably the same
in view of the synthesis easiness. R² and R^{2'} represent an alkyl
group or a silyl group having a substituent. R³ and R^{3'} represent an
alkyl group. From a viewpoint of improving solubility of the
20 resulting polymer, R², R^{2'}, R³ and R^{3'} are preferable to have a certain
molecular chain length (for example, R³ and R^{3'} are an alkyl group
having a carbon number of 1-20), but are not limited thereto. R² and
R^{2'}, and R³ and R^{3'} may be different or the same.

[0024] Also, the polymer compound according to the invention
25 has a structure represented by the following formula in its main chain.

[0025] [Formula 10]

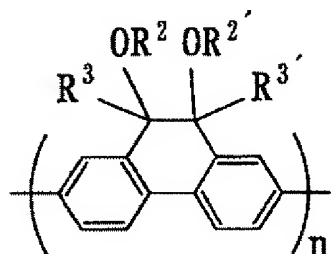


In the formula, R^2 and $R^{2'}$ represent an alkyl group or a silyl group having a substituent (hereinafter may be referred to as a substituted silyl group), and R^3 and $R^{3'}$ represent a hydrogen or an alkyl group. R^2 and $R^{2'}$, and R^3 and $R^{3'}$ may be different or the same. That is, the polymer compound of the invention is not particularly limited about its structure, as far as it has the structure represented by [Formula 10] in its main chain, and may have another constitutional unit (for example, ones derived from pyridine, phenanthrene, thiophene and so on) within a range not obstructing the heat resistance, fluorescence and electrochemical activity in addition to the repeating constitutional unit represented by [Formula 10], but is particularly preferable to be the polymer compound composed of the structure represented by [Formula 10]. In this case, it may be a homopolymer having the same repeating constitutional unit of [Formula 10], or a copolymer having a combination of different repeating constitutional units of [Formula 10], but is preferable to be the homopolymer in view of synthesis easiness and characteristics.

[0026] The molecular weight of the polymer compound according to the invention is not particularly limited in accordance with its applications, but is preferably not less than 1000, and more preferably 3000-100000 as a weight average molecular weight. The polymer has advantages that the molding is easy and the strength of the molded product is improved as it has such a molecular weight.

[0027] Also, the polymer compound according to the invention is represented by the following formula.

[0028] [Formula 11]



In the formula, R^2 and $R^{2'}$ represent an alkyl group or a substituted silyl group, and R^3 and $R^{3'}$ represent a hydrogen or an alkyl group.

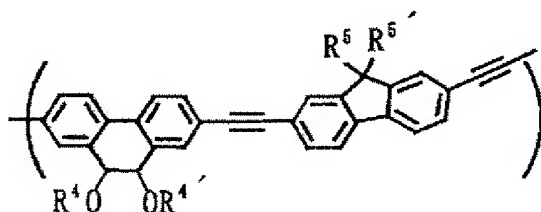
5 R^2 and $R^{2'}$, and R^3 and $R^{3'}$ may be different or the same. Moreover, n represents a polymerization degree and is 5-1000. Since the polymer compound of the invention has solubility in an organic solvent such as chloroform or the like, it is easy to apply a solution of the polymer compound onto a substrate such as a glass or the like.

10 From a viewpoint of the improvement of the solubility, R^2 and $R^{2'}$ are desirable to be silyl group having an approximately C1-C20 alkyl group and R^3 and $R^{3'}$ are desirable to be an approximately C1-C20 alkyl group, but they are not particularly limited to them.

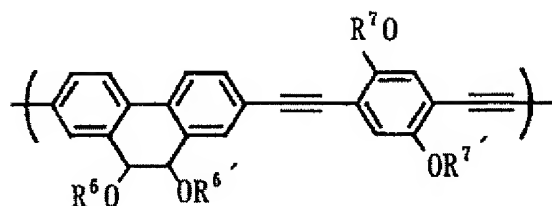
[0029] Moreover, in a preferable embodiment of the polymer

15 compound according to the invention, it is composed of a copolymer comprising a structure represented by the formula described in claim 3 and another structure. Such a copolymer is not particularly limited, but for example, includes at least one selected from the group consisting of the following formulae:

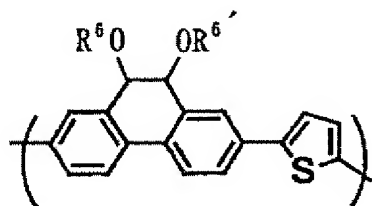
20 [0030] [Formula 12]



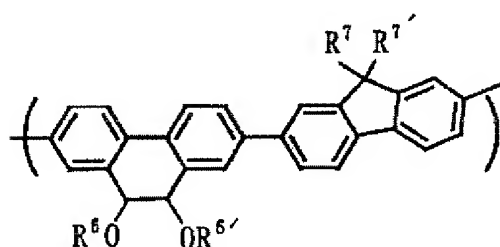
[0031] [Formula 13]



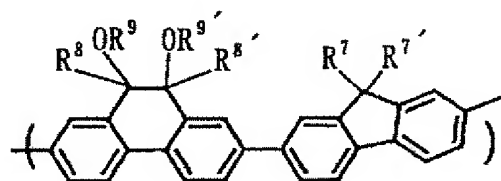
[0032] [Formula 14]



5 [0033] [Formula 15]



[0034] [Formula 16]



10 (wherein R^4 , $R^{4'}$, R^5 and $R^{5'}$ represent an alkyl group, R^6 and $R^{6'}$ represent a silyl group having a substituent, R^7 , $R^{7'}$, R^8 , $R^{8'}$, R^9 and $R^{9'}$ represent an alkyl group, and R^4 and $R^{4'}$, R^5 and $R^{5'}$, R^6 and $R^{6'}$, R^7 and $R^{7'}$, R^8 and $R^{8'}$, and R^9 and $R^{9'}$ may be different or the same).

[0035] The method for producing the polymer compound according to the invention will be described below. In the method for producing the polymer compound according to the invention, the polymer compound of the invention can be obtained by dehalogenation-polymerizing the above-described dihalide. In a preferable embodiment, the dehalogenation-polymerization is carried

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out in the presence of a palladium or nickel compound in view of the high reactivity.

[0036] As a metal or a metal compound used for the homopolymer of the invention are mentioned various ones. At first, as the metal is
5 desirable a reducing metal or a metal causing a C-C coupling reaction of an organic halide, and mention may be made of metals of Group 1 such as Li, Na, K and so on; metals of Group 2 such as Mg, Ca and so on; transition metals such as Ti, V, Cr, Fe, Co, Ni, Cu and so on; metals of Group 12 such as Zn and so on; metals of Group 13 such as
10 Al, Ga and so on; and metals of Group 14 such as Sn and so on. As the metal can be used catalysts comprising other metals or metal compounds, if necessary (there is described an example in which a nickel compound is used as a catalyst in a similar polymerization using Mg in the formula (1) of "Polymer", vol. 46, p68 (1997)).
15 Also, the metal compound is not particularly limited, but is preferable to be a reducing metal compound or one causing a C-C coupling reaction of an organic halide, and includes, for example, a zero-valent nickel compound, a zero-valent palladium compound and the like. When these zero-valent metal compounds are used, they may be used
20 in themselves or they may be produced by adding a divalent nickel compound, a divalent palladium compound or the like and using a reducing agent such as Zn, hydrazine or the like in a reaction system. As a single polymerization system using the zero-valent nickel compound and accompanying a formation of C-C bond is mentioned
25 the polymerization system described in JP-A-H06-42428. Also, in the coupling reaction using a palladium catalyst can be used a coupling reaction of an acetylene $R^{10}C\equiv C-$ with an organic halide $R^{15}X$, or a coupling reaction of an organic tin or boron compound (for example, $R^{12}SnR^{13}_3$ or $R^{14}Sn-B(OR^{15})_3$) with a $R^{11}X$.
30 [0037] Among them, the palladium or nickel compound is preferable in view of high reactivity. In case of obtaining the homopolymer, it is preferable to use a zero-valent nickel complex (for example, bis(1,5-cyclooctadiene) nickel : $Ni(cod)_2$).

[0038] Such a reaction may be performed by using an organic solvent such as dimethylformamide (DMF) or the like at a temperature of about 20-120°C.

5 [0039] The thus obtained polymer compound can be identified by an elemental analysis, an infrared absorption spectrum (IR) or the like. Also, the molecular weight is determined by a gel permeation chromatography (GPC) method.

[0040] The polymer compound according to the invention is soluble and is expected as a polymer material having a heat resistance,
10 an electrochemical activity and a fluorescence.

[0041] Also, the polymer compound according to the invention can be used as an electrochromic material because it shows an electrochemical reduction accompanied with a change of color. Furthermore, it can be used as an active material for a cell utilizing
15 an oxidation-reduction function. A concrete application method and embodiment thereof are according to well-known ones.

EXAMPLES

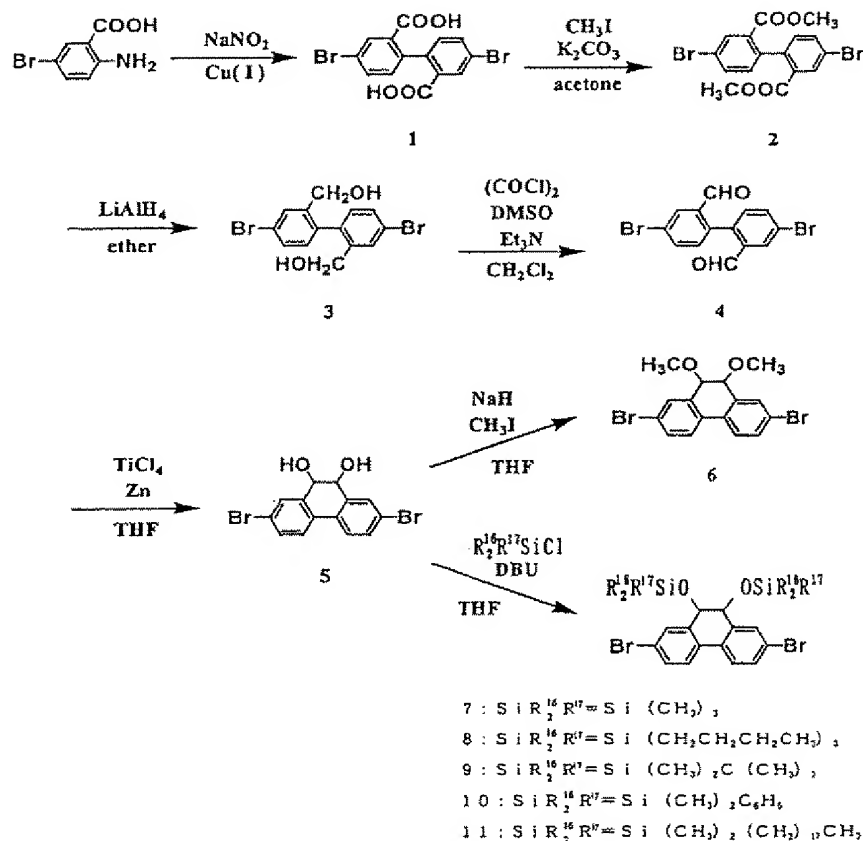
[0042] The following examples are given in illustration of the invention and are not intended as limitations thereof. Moreover,
20 needless to say, they can be properly modified without departing from the scope of the invention.

[0043] Example 1 (Synthesis of dihalide)

A reaction scheme of the dihalide according to the invention is shown below.

25

[0044] [Formula 17]



[0045] (A) Synthesis of 4,4'-dibromo-2,2'-dicarboxy-1,1'-biphenyl (1)

5 To 2-amino-5-bromobenzoic acid (5.47 g, 25.3 mmol) are added H₂O (20 mL) and hydrochloric acid (9 mL), which is cooled to 0°C and further added with sodium nitrite (2.10 g, 30.4 mmol) and stirred for one hour. Then, copper(II) sulfate pentahydrate (12.6 g, 50.5 mmol) is dissolved in H₂O (45 mL) and added with 30% ammonia solution (22 mL), to which is added a solution of hydroxyammonium chloride (3.76 g, 55.7 mmol) in 6N-sodium hydroxide (9 mL) at 0°C and stirred. To the resulting solution is added a diazotized solution dropwise from below a liquid level of the copper solution over 30 minutes. The resulting solution is turned to a room temperature, stirred for 2 hours and heated for one hour.

The solution is made to be acidic with a hydrochloric acid, suction-filtered and dried. 4,4'-Dibromo-2,2'-dicarboxy-1,1'-

biphenyl (4.5 g, 11.3 mmol, 90%) is obtained as a yellow powder by purifying through a column chromatography (hexane: ethyl acetate=1:1). The thus obtained powder is recrystallized with chloroform to obtain a white plate crystal.

5 (Characteristics)

^1H NMR (CD_3OD , 400 MHz)

δ (ppm) = 8.10 (d, $J=1.95\text{Hz}$, 2H, H_a)

7.69 (dd, $J=1.95, 8.30\text{Hz}$, 2H, H_b)

7.10 (d, $J=8.30\text{Hz}$, 2H, H_c)

10 IR (KBr) 3099, 1708, 1585, 1417, 1298, 1281, 1248, 1096, 1003, 826 (cm^{-1}) J. Am. Chem. Soc., 1992, 114, 6227.

In the above characteristics, H_a , H_b and H_c belong to hydrogens bonded with a benzene ring (hereinafter they do likewise in the following examples).

15 (B) Synthesis of 4,4'-dibromo-2,2'-bis(methoxycarbonyl)-1,1'-biphenyl (2)

To 4,4'-dibromo-2,2'-dicarboxy-1,1'-biphenyl (0.18 g, 0.46 mmol) are added potassium carbonate (0.84 g, 6.00 mmol), acetone (25 mL) and iodomethane (170 μL , 2.73 mmol) in a nitrogen
20 atmosphere and refluxed for 2 hours.

The resulting mass is extracted with a chloroform, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (hexane: chloroform=1:1) is obtained 4,4'-dibromo-2,2'-bis(methoxycarbonyl)-
25 1,1'-biphenyl (0.18 g, 0.42 mmol, 91%) as a yellow powder. The thus obtained powder is recrystallized with a mixed solvent of chloroform and hexane to obtain a white plate crystal.

(Characteristics)

^1H NMR (CDCl_3 , 400 MHz)

30 δ (ppm) = 8.16 (d, $J=1.95\text{Hz}$, 2H, H_a)

7.66 (dd, $J=1.95, 8.30\text{Hz}$, 2H, H_b)

7.04 (d, $J=8.30\text{Hz}$, 2H, H_c)

3.66 (s, 6H, $-\text{CH}_3$)

IR (KBr) 1730, 1716, 1434, 1294, 1278, 1244, 1148, 1095, 971, 832
(cm⁻¹)

(C) Synthesis of 4,4'-dibromo-2,2'-bis(hydroxymethyl)-
1,1'-biphenyl (3)

5 4,4'-Dibromo-2,2'-bis(methoxycarbonyl)-1,1'-biphenyl
(3.24 g, 7.56 mmol) is dissolved in a dry ether (42 mL) and stirred at
0°C under a nitrogen atmosphere. Further, the solution is added
with lithium aluminum hydride (0.64 g, 16.9 mmol) and stirred for 6
hours.

10 The resulting mass is extracted with an ethyl acetate, dried with
an anhydrous magnesium sulfate and concentrated. By purifying
through the column chromatography (hexane: ethyl acetate=1:1) is
obtained 4,4'-dibromo-2,2'-bis(hydroxymethyl)-1,1'-biphenyl (2.60 g,
6.98 mmol, 92%) as a white powder. The thus obtained powder is
15 recrystallized with a mixed solvent of chloroform and hexane to
obtain a white plate crystal.

(Characteristics)

¹H NMR (DMSO, 400 MHz)

δ (ppm) = 7.69 (d, J=1.71Hz, 2H, H_a)
20 7.47 (dd, J=2.20, 8.05Hz, 2H, H_b)
 7.02 (d, J=8.05Hz, 2H, H_c)
 5.23 (t, J=5.37Hz, 2H, -OH)
 4.15, 4.05 (dd, J=5.61, 14.1Hz, 2H, -CH₂-)

IR (KBr) 3454, 3320, 1656, 1611, 1567, 1542, 1222, 1161, 957, 822
25 (cm⁻¹)

(D) Synthesis of 4,4'-dibromo-biphenyl-2,2'-
dicarbaldehyde (4)

To a dry CH₂Cl₂ (30 mL) are added oxalyl dichloride (1.11
mL, 12.9 mmol) and dimethyl sulfide (2.00 mL, 28.2 mmol) under a
30 nitrogen atmosphere at -78°C and stirred for 1 hour. Then, it is
added with 4,4'-dibromo-2,2'-bis(methoxycarbonyl)-1,1'-biphenyl
(2.10 g, 5.64 mmol) and triethylamine (7.86 mL, 56.4 mmol) and
stirred for 2 hours.

The resulting mass is extracted with an ethyl acetate, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (hexane: chloroform=2:1) is obtained 4,4'-dibromo-biphenyl-2,2'-dicarbaldehyde (1.87 g, 5.08 mmol, 90%) as a yellow powder. The thus obtained powder is recrystallized with a mixed solvent of chloroform and hexane to obtain a white plate crystal.

(Characteristics)

^1H NMR (CDCl_3 , 400 MHz)

10 δ (ppm) = 9.77 (s, 2H, -CHO)

8.17 (d, $J=2.44\text{Hz}$, 2H, H_a)

7.80 (dd, $J=2.44, 8.30\text{Hz}$, 2H, H_b)

7.21 (d, $J=8.30\text{Hz}$, 2H, H_c)

IR (KBr) 1693, 1682, 1583, 1457, 1389, 1179, 1086, 877, 833, 677

15 (cm^{-1})

(E) Synthesis of 2,7-dibromo-trans-9,10-dihydrophenanthrene-9,10-diol (5)

To a solution of 4,4'-dibromo-biphenyl-2,2'-dicarbaldehyde (2.70 g, 7.33 mmol) dissolved in a dry THF (60 mL) at -78°C is added titanium(IV) chloride (1.21 mL, 11.0 mmol) dropwise under a nitrogen atmosphere, and after 30 minutes zinc (1.44 g, 22.0 mmol) is added and turned to 0°C and stirred for 3 hours.

The resulting mass is extracted with an ethyl acetate, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (hexane: ethyl acetate=3:1) is obtained 2,7-dibromo-trans-9,10-dihydrophenanthrene-9,10-diol (2.17 g, 5.86 mmol, 80%) as a white powder. The thus obtained powder is recrystallized with a mixed solvent of chloroform and hexane to obtain a white plate crystal.

30 (Characteristics)

^1H NMR ($\text{DMSO}-d$, 400 MHz)

δ (ppm) = 7.76 (d, $J=8.29\text{Hz}$, 2H, H_c)

7.71 (dd, $J=2.20, 8.29\text{Hz}$, 2H, H_b)

7.55 (d, J=2.20Hz, 2H, H_a)

5.88 (s, 2H, -benzyl H)

4.47 (s, 2H, -OH)

IR (KBr) 3349, 1459, 1416, 1193, 1141, 1084, 1027, 805, 633, 446

5 (cm⁻¹)

Identification of the monomer is performed by an elemental analysis, IR (KBr method) and ¹H NMR. The characteristics of the thus obtained dihalide are shown below.

	C	H	Br	O
cal	45.44	2.72	43.19	8.65
found	45.32	2.83	42.96	8.91

10

[0046] <Identification of monomer>

Compound 6 in [Formula 17]

(F) Synthesis of 2,7-dibromo-9,10-dihydro-9,10-dimethoxyphenanthrene (6)

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To a solution of 2,7-dibromo-9,10-dihydrophenanthrene-9,10-diol (1.54 g, 4.15 mmol) dissolved in a dry THF (20 mL) are added sodium hydride (0.40 g, 16.7 mmol) and iodomethane (1.5 mL, 23.8 mmol) under a nitrogen atmosphere and stirred for 3 hours at room temperature.

20

The resulting mass is extracted with an ethyl acetate, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (hexane: chloroform=3:1) is obtained 2,7-dibromo-9,10-dihydro-9,10-dimethoxyphenanthrene (1.49 g, 3.74 mmol, 90%) as a white powder.

25

The thus obtained powder is recrystallized with a mixed solvent of chloroform and hexane to obtain a white plate crystal.

Melting point (mp) 150.5-151.5°C

¹H NMR (CDCl₃, 400 MHz)

δ (ppm) = 7.61 (d, J=8.05Hz, 2H, H_c)

30

7.55 (d, J=1.95Hz, 2H, H_a)

7.53 (dd, $J=1.95, 8.29\text{Hz}$, 2H, H_b)

4.32 (s, 2H, -benzyl H)

3.43 (s, 6H, $-\text{CH}_3$)

IR (KBr) 2933, 2894, 2823, 1469, 1207, 1179, 1097, 1005, 881, 819
5 (cm⁻¹)

Elemental Analysis

	C	H	Br	O
calculate	48.27	3.54	40.14	8.04
found	48.08	3.63	40.20	8.19

[0047] In FIG. 1 is shown a NMR spectrum of the above
10 Compound 6.

[0048] Compound 7 in [Formula 17]

(G) Synthesis of 2,7-dibromo-9,10-dihydro-9,10-
bis(trimethylsilyloxy)phenanthrene (7)

To a solution of 2,7-dibromo-9,10-dihydrophenanthrene-
15 9,10-diol (1.43 g, 3.86 mmol) dissolved in a dry THF (5 mL) are
added chlorotrimethylsilane (1.5 mL, 11.8 mmol) and triethylamine (5
mL, 35.9 mmol) under a nitrogen atmosphere and stirred for 5 hours
under reflux.

The resulting mass is extracted with an ethyl acetate, dried
20 with an anhydrous magnesium sulfate and concentrated. By
purifying through the column chromatography (hexane:
chloroform=1:1) is obtained 2,7-dibromo-9,10-dihydro-9,10-
bis(trimethylsilyloxy)phenanthrene (1.60 g, 3.11 mmol, 81%) as a
white powder. The thus obtained powder is recrystallized with a
25 mixed solvent of chloroform and hexane to obtain a white plate
crystal.

(Characteristics)

mp 144.0-145.0°C

¹H NMR (CDCl₃, 400 MHz)

30 δ (ppm) = 7.67 (d, $J=0.49\text{Hz}$, 2H, H_c)

7.53-7.30 (dd, $J=0.73\text{Hz}$, 4H, H_b , H_a)

4.66 (s, 2H, -benzyl H)

0.28 (s, 18H, $-\text{CH}_3$)

IR (KBr) 1253, 1190, 1158, 1096, 924, 908, 883, 867, 838, 808 (cm^{-1})

5

	C	H	Br
cal	46.70	5.09	31.07
found	46.48	4.75	31.65

[0049] In FIG. 2 is shown a NMR spectrum of the above
Compound 7. In the following description, a NMR spectrum is a
1H-NMR spectrum, and H_a - H_c belong to hydrogens bonded with a
10 benzene ring.

[0050] Compound 8 in [Formula 17]

(H) Synthesis of 2,7-dibromo-trans-9,10-dihydro-9,10-
bis(tributylsilyloxy)phenanthrene (8)

To a solution of 2,7-dibromo-trans-9,10-
15 dihydrophenanthrene-9,10-diol (1.88 g, 5.08 mmol) dissolved in a dry
THF (30 mL) are added chlorotributylsilane (3.0 mL, 11.2 mmol) and
1,8-diazabicyclo[5.4.0]-7-undecene (1.9 mL, 12.7 mmol) under a
nitrogen atmosphere and stirred for 5 hours at room temperature.

The resulting mass is extracted with an ethyl acetate, dried
20 with an anhydrous magnesium sulfate and concentrated. By
purifying through the column chromatography (hexane:
chloroform=1:4) is obtained 2,7-dibromo-trans-9,10-dihydro-9,10-
bis(tributylsilyloxy)phenanthrene (3.7 g, 4.83 mmol, 95%) as a white
oil.

25 (Characteristics)

Oil

^1H NMR (CDCl_3 , 400 MHz)

δ (ppm) = 7.54 (d, $J=8.05\text{Hz}$, 2H, H_c)

7.49 (dd, $J=2.20, 7.09\text{Hz}$, 2H, H_b)

30 7.46 (d, $J=2.30\text{Hz}$, 2H, H_a)

4.56 (s, 2H, -benzyl H)
 1.30-1.18 (m, 24H, -CH₂CH₂-)
 0.85 (t, J=6.83, 7.32Hz, 18H, -CH₃)
 0.60-0.56 (b, 12H, -SiCH₂-)

5 IR (KBr) 2956, 2923, 2871, 1464, 1195, 1082, 1005, 906, 886, 812
 (cm⁻¹)

	C	H	Br
cal	59.51	8.15	20.84
found	59.80	7.96	19.64

[0051] In FIG. 8 is shown a NMR spectrum of the above
 10 Compound 8.

[0052] Compound 9 in [Formula 17]

(I) Synthesis of 2,7-dibromo-trans-9,10-dihydro-9,10-
 bis(tert-butyldimethylsilyloxy)phenanthrene (9)

To a solution of 2,7-dibromo-trans-9,10-
 15 dihydrophenanthrene-9,10-diol (0.94 g, 2.54 mmol) dissolved in a dry
 THF (15mL) are added tert-butyldimethylsilane (1.91 g, 12.7 mmol)
 and 1,8-diazabicyclo[5.4.0]-7-undecene (2.3 mL, 15.4 mmol) under a
 nitrogen atmosphere and stirred for 14 hours at room temperature.

The resulting mass is extracted with an ethyl acetate, dried
 20 with an anhydrous magnesium sulfate and concentrated. By
 purifying through the column chromatography (hexane:
 chloroform=1:1) is obtained 2,7-dibromo-trans-9,10-dihydro-9,10-
 bis(tert-butyldimethylsilyloxy) phenanthrene (1.35 g, 2.26 mmol,
 89%) as a white powder. The thus obtained powder is recrystallized
 25 with a mixed solvent of chloroform and hexane to obtain a white plate
 crystal.

(Characteristics)

mp 162.0-163.0°C

¹H NMR (CDCl₃, 400 MHz)

30 δ (ppm) = 7.57-7.46 (m, 6H, H_a, H_b, H_c)

4.57 (s, 2H, -benzyl-H)
 0.85 (s, 18H, -C(CH₃)₃)
 0.14-0.06 (s, 12H, -Si(CH₃)₂)

IR (KBr) 2953, 2928, 1471, 1257, 1083, 910, 845, 837, 814, 775 (cm⁻¹)

5 ¹)

	C	H	Br
cal	52.17	6.40	26.70
found	52.21	6.37	27.00

[0053] In FIG. 4 is shown a NMR spectrum of the above
 Compound 9.

10 [0054] Compound 10 in [Formula 17]

(J) Synthesis of 2,7-dibromo-trans-9,10-dihydro-9,10-
 bis(dimethylphenylsilyloxy)phenanthrene (10)

To a solution of 2,7-dibromo-trans-9,10-
 dihydrophenanthrene-9,10-diol (0.70 g, 1.89 mmol) dissolved in a dry
 15 THF (10 mL) are added chlorodimethylphenylsilane (1 mL, 5.96
 mmol) and 1,8-diazabicyclo[5.4.0.]-7-undecene (1.7 mL, 11.4 mmol)
 under a nitrogen atmosphere and stirred for 3 hours at room
 temperature.

The resulting mass is extracted with an ethyl acetate, dried
 20 with an anhydrous magnesium sulfate and concentrated. By
 purifying through the column chromatography (hexane:
 chloroform=5:1) is obtained 2,7-dibromo-trans-9,10-dihydro-9,10-
 bis(dimethylphenylsilyloxy) phenanthrene (0.79 g, 1.24 mmol, 65%)
 as a white solid.

25 (Characteristics)

mp 103.0-104.0°C

¹H NMR (CDCl₃, 400 MHz)

δ (ppm) = 7.52-7.34 (m, 16H, H_a, H_b, H_c, -Ph)

4.61 (s, 2H, -benzyl H)

30 0.35, 0.32 (s, 12H, -CH₃)

IR (KBr) 1254, 1117, 1053, 912, 866, 845, 826, 786, 736, 698 (cm⁻¹)

[0055] In FIG. 5 is shown a NMR spectrum of the above
Compound 10.

[0056] Compound 11 in [Formula 17]

5 (K) Synthesis of 2,7-dibromo-trans-9,10-dihydro-9,10-
bis(dimethyloctadecylsilyloxy)phenanthrene (11)

To a solution of 2,7-dibromo-trans-9,10-
dihydrophenanthrene-9,10-diol (1.19 g, 3.22 mmol) dissolved in a dry
THF (20 mL) are added chlorodimethyloctadecylsilane (4.47 g, 12.9
10 mmol) and 1,8-diazabicyclo[5.4.0.]-7-undecene (2.4 mL, 16.0 mmol)
under a nitrogen atmosphere and refluxed for 5 hours.

The resulting mass is extracted with an ethyl acetate, dried
with an anhydrous magnesium sulfate and concentrated. By
purifying through the column chromatography (hexane:
15 chloroform=5:1) is obtained 2,7-dibromo-trans-9,10-dihydro-9,10-
bis(dimethyloctadecylsilyloxy) phenanthrene (1.81 g, 1.83 mmol,
57%) as a white solid.

(Characteristics)

mp 51.5-52.5°C

20 ¹H NMR (CDCl₃, 400 MHz)

δ (ppm) = 7.60, 7.47 (s, 6H, H_a, H_b, H_c)

4.57 (s, 2H, -benzyl H)

1.24 (br, 64H, -CH₂-)

0.86 (t, 6H, -CH₃)

25 0.69 (t, 4H, -SiCH₂-)

0.18, 0.15 (s, 12H, -Si(CH₃)₃)

IR (KBr) 2955, 2917, 2850, 1471, 1253, 1192, 1158, 1098, 856, 809
(cm⁻¹)

	C	H	Br
cal	65.43	9.56	16.12
found	65.44	9.38	16.28

30

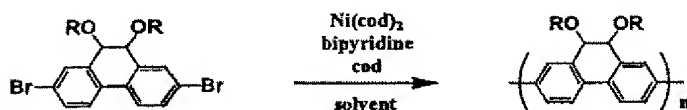
[0057] In FIG. 6 is shown a NMR spectrum of the above Compound 11.

[0058] Example 2

Then, the synthesis of a polymer is tried by using the
5 dihalides obtained as mentioned above as a starting material. That is, the synthesis of the polymer compound according to the invention is tried by polycondensation of a dihalide of 9,10-dihydrophenanthrene having a substituent as a starting material.

[0059] A simplified synthesis procedure example is shown below.

10 [0060] [Formula 18]



(A) Polymerization of homopolymer

The polymerization of 18-SiBu₃ is shown as an example.

To bis(1,5-cyclooctadiene)nickel(0) (0.60 g, 2.18 mmol)
15 are added dry DMF (15.0 mL), bipyridine (0.34 g, 2.18 mmol) and 1,5-cyclooctadiene (267 μ m, 2.18 mmol) under a nitrogen atmosphere, further added a solution of 2,7-dibromo-trans-9,10-dihydro-9,10-bis(tributylsilyloxy)phenanthrene (0.75 g, 0.98 mmol) in dry DMF (5mL) and stirred at 60°C for 4 days.

20 The resulting solution is quenched with hydrobromic acid, reprecipitated twice with methanol and EDTA-4Na aq and dried to obtain a polymer (0.58 g, 0.96 mmol, 96%) as a blue solid.

[0061] The characteristics of the thus obtained polymer are shown in the following Table 1.

25

[0062] [Table 1]

run	R	Solvent	Time day	Yield %	Polymer	Number average molecular weight (M_n^a)	Dispersity (M_w/M_n^a)
1	CH_3	DMF	2d	98	17	1,100 ^b	1.2 ^b
2	$SiBu_3$	DMF	4d	96	18	9,800	2.0
3	$Si(CH_3)_2C(CH_3)_3$	Toluene/DMF 7 : 3	4d	95	19	3,500 ^b	1.1 ^b
4	$Si(CH_3)_2Ph$	DMF	4d	50	20	1,300 ^b	1.2 ^b
5	$Si(CH_3)_2(CH_2)_{17}CH_3$	Toluene/DMF 7 : 3	4d	4d	21	69,000	3.0

The characteristics of the resulting polymers are as follows. At first, as to the solubility, the polymers in runs 2 and 5 of Table 1 and in formula 22 (paragraph number [0070]) of [Formula 20] are soluble in chloroform, THF and toluene, and the polymers in runs 1, 3 and 4 are slightly soluble in chloroform.

As to the data of fluorescence, run 2 shows emissions at λ_{EX} (excitation wavelength) = 379 nm and λ_{EM} (emission wavelength) = 414 nm in a chloroform solution, and shows emissions at λ_{EX} (excitation wavelength) = 391 nm and λ_{EM} (emission wavelength) = 431 nm as a film.

Run 5 shows emissions at λ_{EX} (excitation wavelength) = 398 nm and λ_{EM} (emission wavelength) = 427 nm in a chloroform solution, and shows emissions at λ_{EX} (excitation wavelength) = 398 nm and λ_{EM} (emission wavelength) = 430 nm as a film.

The formula 22 of [Formula 20] shows emissions at λ_{EX} (excitation wavelength) = 385 nm and λ_{EM} (emission wavelength) = 418 nm in a chloroform solution, and shows emissions at λ_{EX} (excitation wavelength) = 382 nm and λ_{EM} (emission wavelength) = 432 nm as a film.

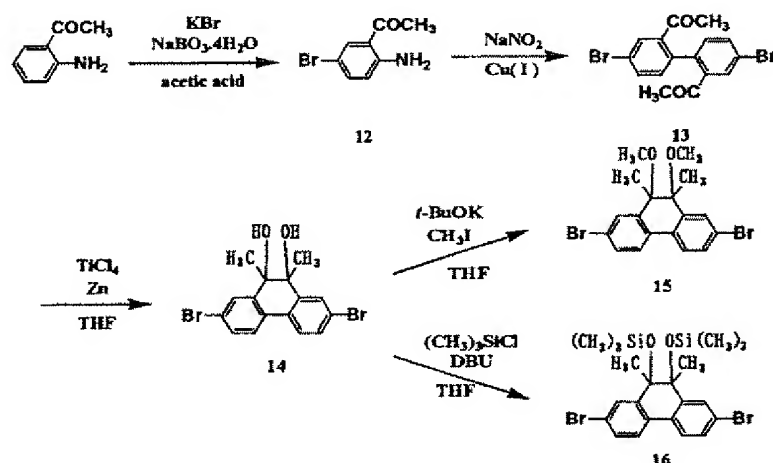
As to CV, run 2 shows an oxidation wave at 1.33 V. Run 5 shows an oxidation wave at 1.34 V. Run 6 shows an oxidation wave at 1.16 V. CV means an oxidation wave of a polymer film in a cyclic voltammetry (CV). Moreover, values such as voltage of 1.33V and so on are values corresponding to Ag^+/Ag .

As to the heat resistance, the temperature of 5% weight reduction shows 390°C in run 2, 360°C in run 5, and 400°C in the formula 22 of [Formula 20], from which it is understood that the thermal stability is high.

[0063] Example 3

Then, a reaction scheme of a dihalide according to the invention in another embodiment is shown below.

[0064] [Formula 19]



[0065] (L) Synthesis of 2-amino-5-bromoacetophenone (12)

To 2-aminoacetophenone (20.0 g, 148 mmol) and potassium bromide (21.2 g, 178 mmol) is added AcOH (60 mL) under a nitrogen atmosphere, which is cooled to 0°C and added with sodium peroxoborate tetrahydrate (27.3 g, 178 mmol) and stirred for 2 days.

The resulting mass is extracted with a chloroform, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (hexane: chloroform=1:1) is obtained 2-amino-5-bromoacetophenone (27.4 g, 128 mmol, 86%) as a yellow powder. The thus obtained powder is

recrystallized with a mixed solvent of chloroform and hexane to obtain a yellow needle-like crystal.

(Characteristics)

^1H NMR (CDCl_3 , 400 MHz)

5 δ (ppm) = 7.80 (d, $J=2.44\text{Hz}$, 1H, H_a)

7.32 (dd, $J=1.95, 8.79\text{Hz}$, 1H, H_b)

6.56 (d, $J=8.79\text{Hz}$, 1H, H_c)

6.29 (s, 2H, $-\text{NH}_2$)

2.56 (s, 3H, $-\text{OCH}_3$)

10 IR (KBr) 3314, 1469, 1394, 1186, 1089, 1036, 1004, 847, 816, 518 (cm^{-1})

(M) Synthesis of 1-(2'-acetyl-4,4'-dibromo-biphenyl-2-yl)ethanone (13)

To 2-Amino-5-bromoacetophenone (17.4 g, 81.0 mmol) are
15 added H_2O (28 mL) and hydrochloric acid (24 mL), which is cooled to 0°C , further added with sodium nitrite (6.71 g, 97.2 mmol) and stirred for 1 hour. Then, a solution of copper(II) sulfate pentahydrate (40.5 g, 162 mmol) dissolved in H_2O (140 mL) and added with 30% of ammonia solution (70 mL) is added with a
20 solution of hydroxyammonium chloride (12.0 g, 178 mmol) in 6N-sodium hydroxide (30 mL) at 0°C and stirred. To this solution is added dropwise a diazotized solution from below a liquid level of the copper solution over 30 minutes. The resulting solution is turned to a room temperature and stirred for 2 hours. Thereafter, it is heated
25 for 1 hour.

After the solution is acidified with hydrochloric acid, it is extracted with a chloroform, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (silica, hexane: chloroform=1:1) is obtained 1-(2'-
30 acetyl-4,4'-dibromo-biphenyl-2-yl)ethanone (16.0 g, 40.4 mmol, 99%) as a yellow powder. The thus obtained powder is recrystallized with a mixed solvent of chloroform and hexane to obtain a white plate crystal.

(Characteristics)

^1H NMR (CDCl_3 , 400 MHz)

δ (ppm) = 7.86 (d, $J=2.44\text{Hz}$, 2H, H_a)

7.62 (dd, $J=1.95, 8.00\text{Hz}$, 2H, H_b)

5 7.01 (d, $J=8.00\text{Hz}$, 2H, H_c)

2.33 (s, 6H, $-\text{OCH}_3$)

(N) Synthesis of 2,7-dibromo-trans-9,10-dimethylphenanthrene-9,10-diol (14)

To a solution of 1-(2'-acetyl-4,4'-dibromo-biphenyl-2-yl)ethanone (10.7 g, 27.0 mmol) dissolved in dry THF (150 mL) is added dropwise titanium(IV) chloride (4.44 mL, 40.5 mmol) under a nitrogen atmosphere, which is added with zinc (5.29 g, 80.9 mmol) after 30 minutes, turned to 0°C and stirred for 3 hours.

The resulting mass is extracted with an ethyl acetate, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (hexane: ethyl acetate=3:1) is obtained 2,7-dibromo-trans-9,10-dimethylphenanthrene-9,10-diol (9.57 g, 24.0 mmol, 89%) as a yellow solid.

20 (Characteristics)

^1H NMR (CDCl_3 , 400 MHz)

δ (ppm) = 7.85 (d, $J=1.95\text{Hz}$, 2H, H_a)

7.51 (d, $J=8.30\text{Hz}$, 2H, H_c)

7.46 (dd, $J=1.95, 8.30\text{Hz}$, 2H, H_b)

25 2.50 (s, 2H, $-\text{OH}$)

1.30 (s, 6H, $-\text{CH}_3$)

IR (KBr) 3447, 1463, 1365, 1178, 1096, 1056, 950, 930, 809, 685 (cm^{-1})

The identification of the monomer is performed by an elemental analysis, IR (KBr method) and ^1H NMR. The characteristics of the dihalide thus obtained are shown below.

[0066] Compound 15 in [Formula 19]

(O) Synthesis of 2,7-dibromo-trans-9,10-dimethoxy-9,10-

dimethylphenanthrene (15)

To a solution of 2,7-dibromo-trans-9,10-dimethylphenanthrene-9,10-diol (2.71 g, 6.81 mmol) dissolved in dry THF (20 mL) is added potassium tert-butoxide (3.28 g, 29.2 mmol) under a nitrogen atmosphere and stirred at room temperature for 3 hours. Then, it is added with iodomethane (6.00 mL, 96.4 mmol) and stirred under reflux for 4 days.

The resulting mass is extracted with a chloroform and a sodium thiosulfate, dried with an anhydrous magnesium sulfate and concentrated. By purifying through the column chromatography (hexane: chloroform=3:1) is obtained 2,7-dibromo-trans-9,10-dimethoxy-9,10-dimethylphenanthrene (0.50 g, 1.17 mmol, 17%) as a white powder. The thus obtained powder is recrystallized with a mixed solvent of chloroform and hexane to obtain a white plate crystal.

(Characteristics)

mp 202.5-203.0°C

¹H NMR (DMSO-d, 400 MHz)

δ (ppm) = 7.77 (d, J=8.30Hz, 2H, H_c)

7.66 (d, J=2.20Hz, 2H, H_a)

7.57 (dd, J=1.95, 8.29Hz, 2H, H_b)

3.29 (s, 6H, -OCH₃)

1.54 (s, 6H, -CH₃)

IR (KBr) 1476, 1461, 1250, 1206, 1118, 1078, 1037, 1004, 810, 795

(cm⁻¹)

	C	H	Br	O
cal	50.73	4.26	37.50	7.51
found	50.45	4.13	37.18	7.52

[0067] In FIG. 7 is shown a NMR spectrum of the above compound 15.

30 [0068] Compound 16 in [Formula 19]

(P) Synthesis of 2,7-dibromo-trans-9,10-dimethyl-9,10-bis(trimethylsilyloxy)phenanthrene (16)

To a solution of 2,7-dibromo-trans-9,10-dimethylphenanthrene-9,10-diol (3.50 g, 8.79 mmol) dissolved in dry
5 THF (30 mL) are added chlorotrimethylsilane (4.46 mL, 35.1 mmol) and 1,8-diazabicyclo[5.4.0.]-7-undecene (10 mL, 71.7 mmol) under a nitrogen atmosphere and stirred under reflux for 7 hours.

The resulting mass is extracted with an ethyl acetate, dried with an anhydrous magnesium sulfate and concentrated. By
10 purifying through the column chromatography (hexane: chloroform=3:1) is obtained 2,7-dibromo-trans-9,10-dimethyl-9,10-bis(trimethylsilyloxy)phenanthrene (3.93 g, 7.24 mmol, 82%) as a white powder. The thus obtained powder is recrystallized with a mixed solvent of chloroform and hexane to obtain a white plate
15 crystal.

(Characteristics)

mp 140.0-141.0°C

¹H NMR (CDCl₃, 400 MHz)

δ (ppm) = 7.65 (d, J=1.71Hz, 2H, H_a)
20 7.40-7.46 (m, 4H, H_b, H_c)
1.34 (s, 6H, -CH₃)
0.33 (s, 18H, -(CH₃)₃)

IR (KBr) 1264, 1252, 1219, 1155, 1114, 1070, 1019, 888, 861, 839
(cm⁻¹)

25 [0069] In FIG. 8 is shown a NMR spectrum of the above compound 16.

[0070] Example 4

Then, the synthesis of a polymer is tried by using the above-obtained dihalides as a starting material. That is, the
30 synthesis of the polymer compound according to the invention is tried by polycondensing a dihalide of 9,10-dihydrophenanthrene having a substituent as a starting material.

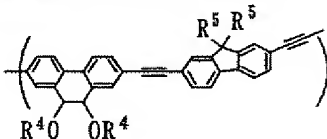
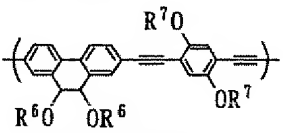
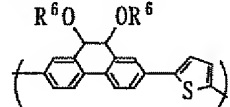
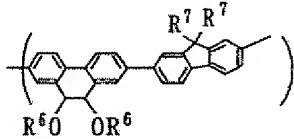
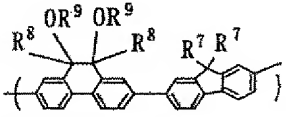
[0071] The simplified synthesis procedure of the homopolymer is

further added 9,9-dioctylfluorene-2,7-bis(trimethyleneborate) (0.56 g, 1.00 mmol), 2,7-dibromo-trans-9,10-dimethoxyl-9,10-dimethylphenanthrene (0.43 g, 1.00 mmol), 2M of bubbled potassium carbonate (5.0 mL) and methanol (5.0 mL) and stirred at 80°C for 4 days.

The resulting solution is reprecipitated with methanol and EDTA-4Na aq and dried to obtain a polymer (0.65 g, 1.00 mmol, 99%) as a green powder.

[0072] Characteristics of the polymers obtained in the above (A) and (B) are shown in the following Table 2.

[0073] [Table 2]

	Time h	Yield %	Polymer	Number average molecular weight (Mn ^a)	Dispersity (Mw/Mn ^a)
 $R^4=CH_3, R^5=n-C_8H_{17}$	4d	98	27	7000	3.0
 $R^6=Si(n-C_4H_9)_3, R^7=n-C_{12}H_{25}$	4d	98	28	8500 2300	2.4 1.1
 $R^5=Si(n-C_4H_9)_3$	4d	96	29	3100	1.3
 $R^6=Si(n-C_4H_9)_3, R^7=n-C_8H_{17}$	4d	97	30	6600	2.2
 $R^7=n-C_8H_{17}, R^8=CH_3, R^9=CH_3$	4d	98	31	21000	2.4

^a Determined by GPC (eluent:CHCl₃)

Each of the homopolymers and copolymers obtained according to the invention is dissolved in an organic solvent such as

chloroform or the like, and the resulting solution is applied onto a glass or a metal plate of platinum or the like and dried at room temperature in air to obtain a polymer thin film. The resulting thin film has a strength durable to a visible-ultraviolet fluorescence spectroscopy and an electrochemical measurement. Also, the deterioration is not observed even if the thin film is left to stand in air.

The homopolymer (22) is mentioned as an example.

The solution of the polymer in chloroform (about 1.5×10^{-5} M) is applied over a full surface of a nonfluorescent glass (2 cm \times 5 cm) and then dried at room temperature in air to obtain an uniform thin film. As a fluorescence spectrum of the filmed polymer is measured (excitation wavelength 382 nm), an emission peak is observed at 432 and 454 nm.

[0074] Example 5

Then, ultraviolet spectrum and fluorescence spectrum are measured to the polymer compounds of the invention obtained in Examples 2 and 4. The results are shown in Tables 3 and 4.

Table 3 shows optical characteristics of the homopolymer.

20

[0075] [Table 3]

(Optical characteristics of Homopolymer)

run	Polymer	Absorbance		Fluorescence		Quantum yield Φ (%)
		λ_{max} /nm		λ_{max} (EM)/nm (λ_{max} (EX)/nm)		
		CHCl ₃ soln.	film	CHCl ₃ soln.	film	
1	17-CH ₃	351		410 (361)		89
2	18-SiBu ₃	378	392, 415	414, 438 (379)	431, 456, 486 (391)	100
3	19-Si (CH ₃) ₂ C(CH ₃) ₃	382	384	415 (373)	434, 457, 486 (370)	82
4	20-Si (CH ₃) ₂ Ph	367		412, 434 (367)		86
5	21-Si (CH ₃) ₂ (CH ₂) ₁₇ CH ₃	410	393, 411	427, 454 (398)	430, 456 (398)	62
6	22-Si (CH ₃) ₃ -CH ₃	382	392	418, 440 (385)	432, 454 (382)	100

Table 4 shows optical characteristics of the copolymer.

[0076] [Table 4]

(Optical characteristics of Copolymer)

run	Polymer	Absorbance		Fluorescence		Quantum yield Φ (%)
		λ_{\max} /nm		λ_{\max} (EM)/nm (λ_{\max} (EX)/nm)		
		CHCl ₃ soln.	film	CHCl ₃ soln.	film	
1	27-CH ₃ -FL-Acetyl	390,408	397,421	423,447 (410)	480,508 (436)	82
2	28-SiBu ₃ -Ph-Acetyl	333,386	333,387	441 (333,397)	517 (398)	53
3	29-SiBu ₃ -Thiophene	405	404	464,485 (412)	480,505 (399)	89
4	30-SiBu ₃ -FL	377	382	416,439 (378)	428,453 (378)	89
5	31-CH ₃ -CH ₃ -FL	387	382	418,443 (389)	428,453 (371)	84

[0077] These results show absorption points of light from the visible-ultraviolet absorption spectrum, from which it is found that the polymer can be used for a coloring material about the absorption at a visible portion and an ultraviolet light absorber. Moreover, since emission is observed in the emission spectrum (fluorescence spectrum), it is found that the polymer can be used in a fluorescent paint or the like.

Since the polymer compound according to the invention shows the solubility in an organic solvent such as chloroform or the like, it is easy to apply the solution of the polymer compound onto a substrate such as glass or the like.

INDUSTRIAL APPLICABILITY

[0078] According to the invention, there can be provided a functional material or the like having a solubility, an electrochemical activity, a fluorescence, a heat resistance and so on, so that the invention can widely contribute to optical and electrochemical field.